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SEPARATION OF DEPLETED URANIUM
FRAGMENTS FROM GUN TEST CATCH-
MENT, VOL I: SUMMARY AND
RECOMMENDATIONS

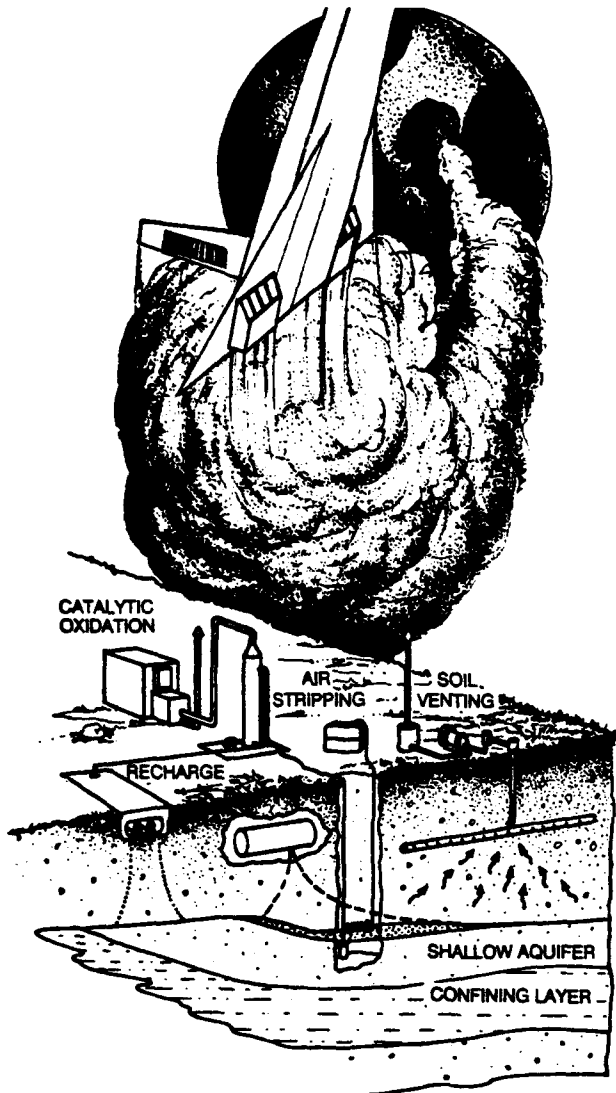
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FINAL REPORT

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13. ABSTRACT (Maximum 200 words) <p>This technical report is divided into four volumes. Volume I presents Summary and recommendations, Volume II contains catchment System Evaluation and Separations Methods, Volume III contains Economic Comparison of Disposal Options, and Volume IV documents Bench-Scale Tests for Separation.</p> <p>Results of activities are described for a task entitled "Separation of Depleted Uranium Fragments from Gun Test Catchments, Vol. I," sponsored by the Air Force Engineering and Services Center, Tyndall Air Force Base. This report presents the results of a series of activities designed to develop an improved method for separating depleted uranium from target materials, principally sand. Recommendations are offered for the most attractive method from both economic and technical perspectives. The search for an improved method considered the environmental, economic, and technical aspects of the problem. The method of choice is to dry, screen, and recycle the intermediate-sized uranium-contaminated sand. This will save the Air Force an estimated several million dollars over the next 20 years and will reduce the volume of low-level waste by about 90 percent.</p>				
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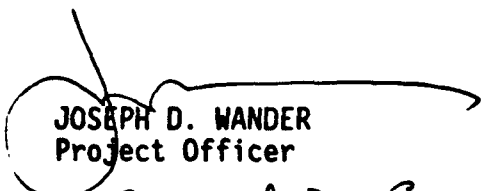
PREFACE

This report was prepared by Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, DE-AC05-84OR21400, for the U.S. Department of Energy (DOE) and the Air Force Civil Engineering Support Agency (AFCEA), Suite 2, 139 Barnes Drive, Tyndall Air Force Base, Florida 32403-5319.

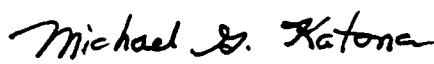
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This technical report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication,


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EXECUTIVE SUMMARY

A. OBJECTIVES

The objectives of this research effort was to develop and demonstrate an improved method of separating depleted uranium (DU) from target sand. The source of the uranium is penetrator projectiles that are test-fired into a target butt as part of an ongoing quality assurance program. The objective of the separation is to reduce disposal costs by reducing the volume of sand that must be discarded.

B. BACKGROUND

As part of an ongoing quality assurance program, Air Force ammunition from storage is sampled periodically for test firing to assure it is in field-ready condition. The test site under consideration, designated TA C-64 at Eglin AFB, provides for the test of the Air Force Gun, Automatic Utility-8 (GAU-8), which fires 30-mm armor-piercing incendiary (API) ammunition, the primary constituent of which is DU. The projectiles are fired by a Gatlin-style, seven-barreled gun mounted in a fixed position inside a building on the test site. The projectiles are fired through an open door in the test building, through two light screens that measure the projectile velocity, through an electronic location (x-y plane) sensing device, and into a dampened sand butt housed in another building about 35 meters (100 feet) away.

The catchment must be maintained to provide adequate safety and environmental protection. Large fragments [>12 millimeters (0.5 inch)] are removed after every 17,000 rounds to prevent ricochets, and the sand is replaced after 70,000 rounds because the fines, produced when the projectiles impact the sand, tend to plug the air filtration system at unacceptably high rates. The sand removed from the butt is a low-level radioactive waste.

The present system is safe and environmentally effective but very expensive. The cost of packaging, transportation, and burial of sand from three butt replacement operations cost \$3,000,000 in 1986-1987. The same operation in 1990 would cost \$4,000,000.¹ The burial cost for low-level waste increased from \$31.50/ft³ to an estimated \$60.00/ft³ in 1990.² The disposal

¹R. J. Lynn, internal correspondence to A. L. Porell, Martin Marietta Energy Systems, Inc., regarding Subcontract 22X-2251V, April 15, 1987.

²Gary Benda, Chem-Nuclear Systems, Inc., personal communication to W. M. Bradshaw, Martin Marietta Energy Systems, Inc., February 8, 1989.

charge for the Southeast Compact is expected to double again in the next 3 years as the new above-ground repository is constructed and brought on-line.³

The program described here responds to the need to develop an equally safe but less costly system for testing DU ammunition.

C. SCOPE

The original statement of work divided the effort into five primary tasks. Task I involved a literature review that included (1) an evaluation of the present test firing procedures at Eglin AFB to determine the feasibility of alternatives to the present operating procedures and catchment media cleanup system, (2) a review of previous efforts to reduce the waste, (3) an evaluation of the potential for recycling DU, (4) a review of previous efforts to remove the DU from the sand, and (5) an evaluation of other separation procedures. Task I also included an analysis of the uranium-contaminated sand being produced. In Task II, a research plan was developed for those technologies determined in the literature search to exhibit a high potential for DU removal. An economic analysis of selected separation techniques was conducted in Task III. If the results of Tasks I, II, and III were attractive, Task IV was to involve a pilot scale demonstration of the most promising technology, with the final design and operational requirements to be specified in Task V.

D. METHODOLOGY

Consideration of a range of options revealed that only two substances could meet the above requirements. Both water (or density-enhanced water solutions) and ice, in various physical forms, have the combination of properties that make them attractive as alternative catchment media.

The life-cycle cost of each option was compared using guidelines provided in Air Force Regulation (AFR) 178-1 and Office of Management and Budget (OMB) Circular A-94.

³Gary Benda, Chem-Nuclear Systems, Inc., personal communication to W. M. Bradshaw, Martin Marietta Energy Systems, Inc., September 5, 1989.

E. CONCLUSIONS

Despite the extremely low overall rating, chemical leaching is the only method evaluated that allows unrestricted disposal. All of the comparisons lead to the conclusion that the best available option is for the Air Force to dry, screen, and recycle the intermediate-sized uranium contaminated sand.

The results of Tasks I, II, and III were most attractive, but the technology selected as the most promising did not readily lend itself to an economically justifiable pilot-scale demonstration.

Section	TABLE OF CONTENTS Title	Page
I	INTRODUCTION	1
	A. OBJECTIVES	1
	B. BACKGROUND	1
	C. SCOPE	2
II	TEST CRITERIA	4
	A. CRITERIA FOR THE EGLIN AFB DU TEST FACILITY	4
	1. Operational Criteria	4
	2. Regulatory Criteria	4
	B. DU CATCHMENT ALTERNATIVES	5
	1. Water Catchments	5
	2. Ice Catchments	6
	C. SAND/DU SEPARATION TESTS	6
	1. Dry Magnetic Separation	6
	2. Electrostatic Separation	6
	3. Jigging	7
	4. Shaking Table	7
	5. Static and Moving Belt Separations	7
	6. Rotating Spiral Concentrator	7
	7. Fluidized-Bed Tests	8
	8. Chemical Leaching Tests	8
	9. Screening Separation Tests	8
III	EVALUATION OF SAND/DU SEPARATION METHODS	9
	A. SYSTEMS EVALUATION FOR EGLIN AFB	9
	B. ECONOMIC COMPARISON OF OPTIONS	11
	C. NONECONOMIC COMPARISON OF SYSTEMS	12
	1. Technical Feasibility	12
	2. Health, Safety, and Environmental Risk	12
	3. Complexity	13
IV	CONCLUSIONS AND RECOMMENDATIONS	14
	A. EQUIPMENT PROCUREMENT	14
	REFERENCES	16
	Appendix	
A	TARGET BUTT SAND PHYSICAL CHARACTERIZATION AND SCREENING STUDIES	17
B	SUGGESTED RFP FOR SAND/DEPLETED URANIUM SCREENING AND RECYCLE	48

Table	LIST OF TABLES Title	Page
1.	EVALUATION CATEGORIES	10
2.	PARTIAL LIST OF DATA USED IN ECONOMIC ANALYSIS	11
3.	NONECONOMIC COMPARISON OF SAND/DU TREATMENT SYSTEM	12
A-1.	PERCENT MOISTURE CALCULATION, SAMPLE 1	21
A-2.	DRY SCREEN SIZE DISTRIBUTION, SAMPLE 1	21
A-3.	DISTRIBUTION OF VARIOUS PRODUCTS IN THE COARSE FRACTIONS OF TARGET BUTT SAND, SAMPLE 1	21
A-4.	CALCULATED SCREEN EFFICIENCY (RELATIVE TO 60-MESH), SAMPLE 1	22
A-5.	WET SCREEN SIZE DISTRIBUTION, SAMPLE 1	22
A-6.	TOTAL AND CARBONATE-SOLUBLE URANIUM DISTRIBUTION, SAMPLE 1	23
A-7.	PERCENT MOISTURE CALCULATION, SAMPLE 2	25
A-8.	DRY SCREEN SIZE DISTRIBUTION, SAMPLE 2	25
A-9.	DISTRIBUTION OF VARIOUS PRODUCTS IN THE COARSE FRACTIONS OF TARGET BUTT SAND, SAMPLE 2	25
A-10.	PERCENT MOISTURE CALCULATION, SAMPLE 2	26
A-11.	DRY SCREEN SIZE DISTRIBUTION, SAMPLE 2	27
A-12.	CALCULATED SCREEN EFFICIENCY (RELATIVE TO 60-MESH), SAMPLE 2	27
A-13.	WET SCREEN DISTRIBUTION, SAMPLE 2	28
A-14.	PERCENT MOISTURE CALCULATION, SAMPLE 3	29
A-15.	DRY SCREEN SIZE DISTRIBUTION, SAMPLE 3	30
A-16.	WET SCREEN SIZE DISTRIBUTION, SAMPLE 3	30
A-17.	WET SCREEN SIZE DISTRIBUTION, SAMPLE 3	31
A-18.	TEST RESULTS - MAGNETIC SEPARATION	33
A-19.	TEST RESULTS - JIGGING	34
A-20.	TEST RESULTS - ROTATING SPIRAL CONCENTRATOR	35
A-21.	SAMPLE 1 - 0% MOISTURE	42
A-22.	SAMPLE 2 - 2% MOISTURE	43
A-23.	SAMPLE 3 - 2% MOISTURE	44
A-24.	SAMPLE 2 - 6% MOISTURE	45
A-25.	SCREENING EFFICIENCY BY MESH SIZE	46
B-1.	DESCRIPTION OF SAND/DU MIXTURE	51
B-2.	SUGGESTED SUPPLIERS OF SAND/DU SEPARATION EQUIPMENT	52

SECTION I INTRODUCTION

A. OBJECTIVES

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The catchment must be maintained to provide adequate safety and environmental protection. Large fragments [>12 millimeters (0.5 inch)] are removed after every 17,000 rounds to prevent ricochets, and the sand is replaced after 70,000 rounds because the fines, produced when the projectiles impact the sand, tend to plug the air filtration system at unacceptably high rates. The sand removed from the butt is a low-level radioactive waste.

The present system is safe and environmentally effective but very expensive. The cost of packaging, transportation, and burial of sand from three butt replacement operations cost \$3,000,000 in 1986-1987. The same operation in 1990 would cost \$4,000,000.⁴ The burial cost for low-level waste increased from

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The program described here responds to the need to develop an equally safe but less costly system for testing DU ammunition.

C. SCOPE

The original statement of work divided the effort into five primary tasks. Task I involved a literature review that included (1) an evaluation of the present test firing procedures at Eglin AFB to determine the feasibility of alternatives to the present operating procedures and catchment media cleanup system, (2) a review of previous efforts to reduce the waste, (3) an evaluation of the potential for recycling DU, (4) a review of previous efforts to remove the DU from the sand, and (5) an evaluation of other separation procedures. Task I also included an analysis of the uranium- contaminated sand being produced. In Task II, a research plan was developed for those technologies determined in the literature search to exhibit a high potential for DU removal. A precondition was that the plan receive prior approval and that laboratory testing of at least two separation systems, including magnetic separation and mineral jig separation, be incorporated. An economic analysis of selected separation techniques was conducted in Task III. If the results of Tasks I, II, and III were attractive, Task IV was to involve a pilot scale demonstration of the most promising technology, with the final design and operational requirements to be specified in Task V.

The results of Tasks I, II, and III were most attractive, but the technology selected as the most promising did not readily lend itself to an economically justifiable pilot-scale demonstration. Because each of the individual steps in the selected technology was well understood and the perceived chances for a successful demonstration were great, the decision was made to acquire the equipment required for full- scale implementation of the technology. Another Statement of Work (SOW) was then issued to support this decision. The elements of this SOW included (1) the specification of the equipment necessary to separate the sand/DU mixture, (2) assistance to Air Force personnel in preparing procurement specifications, (3) preparation of the safety analysis and test plan required to

⁵Gary Benda, Chem-Nuclear Systems, Inc., personal communication to W. M. Bradshaw, Martin Marietta Energy Systems, Inc., February 8, 1989.

⁶Gary Benda, Chem-Nuclear Systems, Inc., personal communication to W. M. Bradshaw, Martin Marietta Energy Systems, Inc., September 5, 1989.

conduct the full-scale field demonstration, (4) technical direction and data collection during the test, and (5) a summary report, including data analysis, conclusions, and recommendations for future system improvements.

SECTION II TEST CRITERIA

A. CRITERIA FOR THE EGLIN AFB DU TEST FACILITY

1. Operational Criteria

A sand/DU separation or treatment system will be operated only intermittently, twice a year at most and possibly less than once a year. The principal operational considerations are as follows:

a. The treatment system must be operated by personnel now available at the test site to avoid excessive costs.

b. The system must withstand long inactive periods and be easily maintainable.

c. Since the DU test facility already exists, any new waste treatment method requiring major changes of the existing facility would be at a distinct economic disadvantage relative to methods that may be applied with slight facility impact.

2. Regulatory Criteria

Alternative DU catchment systems must meet Eglin AFB operational needs and ensure compliance with health, safety, and environmental regulations and directives. The U.S. Nuclear Regulatory Commission (NRC) site license limits total DU at the test site to 80,000 kilograms (Reference 1). In practice, this limitation does not affect operations at the test site. Compliance with a variety of industrial hygiene and health physics requirements is achieved through personal protective equipment and radiation monitoring devices.

U.S. Environmental Protection Agency (EPA) regulations limit the activity of solid waste and wastewater discharged to the environment to 35 pCi/gram and 40 pCi/milliliters, respectively (Reference 2). With DU, 35 pCi/gram sand corresponds to ~40-ppm DU (on a mass basis) (Reference 2). Separation processes that provide "clean" sand at an activity greater than 35 pCi/g yield no economic benefit because the "clean" product remains a low-level radioactive waste.

The 40 pCi/milliliters limit for wastewater also affects the selection of separation options. Although past operations have frequently involved contacting water with DU-contaminated sand and have not generated any wastewater with activity in excess of 40 pCi/milliliters, test results prove that this is within the realm of possibility. Limestone in the sand

in the presence of fully oxidized uranium (neither of which is improbable) and mildly acidic water can easily dissolve enough DU to surpass the 40 pCi/milliliters limit (Reference 3).

Although these considerations proved to be quite important in the final selection of the system, the early phases of the project examined a wide range of options, including alternative catchment media in lieu of sand and a broad range of potential separation devices.

B. DU CATCHMENT ALTERNATIVES

The following criteria were included in the study of alternative catchment media for the Eglin AFB gun test facility:

- Easy and complete DU recovery.
- Improved catchment operation (i.e., the cost and time involved in separating DU from sand, as required by the current system, should not be replaced by a different but roughly equivalent effort).
- Safe operation (e.g., no flammable or toxic media could be considered).
- Robust design (i.e., it is believed that systems requiring complex high-speed mechanical devices would be inappropriate for a gun test facility because of the requirement for specialized personnel).

Consideration of a range of options revealed that only two substances could meet the above requirements. Both water (or density-enhanced water solutions) and ice, in various physical forms, have the combination of properties that make them attractive as alternative catchment media.

1. Water Catchments

The primary advantage of water as a stopping medium is that it allows for complete and easy recovery of the DU. A relatively simple system that requires no specialized equipment or sophisticated operating techniques could be built using existing technology. The principal problem the system's behavior following a rapid sequence of nearly collinear bullets. The formation of persistent vapor wakes results in excessive stopping lengths for multiple firing tests. In contrast to a solid, such as sand, the pressures generated by the bullet impacts will be transmitted to the catchment walls. A structure designed specifically to withstand this type of loading would be required for such a system. The addition of large amounts of highly soluble salts can result in a twofold or threefold increase in the density of water and correspondingly will decrease the

required stopping distance. Even this improvement was judged insufficient to qualify water as an alternative media for the present application.

2. Ice Catchments

Ice can combine the favorable properties of both water and sand. Ice may, like sand, absorb the impact forces of the bullets, thus protecting the catchment building from these forces, and could, like water, be easily separated from the DU by simply being melted.

Ice was not recommended as an alternate medium for this application because it requires significant modifications to present facilities and an extensive refrigeration system maintenance program.

A detailed discussion of the alternate catchment media study is contained in Volume II of this report series.

C. SAND/DU SEPARATION TESTS

A number of sand/DU separation methods have been tested in an attempt to reduce the sand activity to 35 pCi/g. The following is a brief review of the equipment tested and the results. A thorough discussion of these efforts is contained in subsequent volumes of this report.

1. Dry Magnetic Separation

No separation was achieved using standard devices with wet or dry feed that rely on ferromagnetism. Tests at Oak Ridge National Laboratory (ORNL) using a paramagnetic separator gave varying results. Occasionally, extremely good separations were achieved, but generally the results were erratic. In no instance was the separation sufficient to permit unrestricted disposal of the cleaned product.⁷

2. Electrostatic Separation

Moderate separations were achieved for relatively large particles (-10/+20-mesh). In this fraction, ~96 percent of the DU in the feed was captured in the waste stream, consisting of 43 percent of the feed. Separations for smaller-sized fractions were not as good. Fine dust formation was a problem except with the coarsest feed (i.e., >20-mesh) (Reference 4).

⁷J. M. Hoegler, "Magnetic Separability of Uranium From Sand," unpublished ORNL report to Eglin Air Force Base, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, 1987.

3. Jigging

Three separate jigging tests were performed. An internal Air Force study reported that a feed activity level of 1000 pCi/gram was reduced to 50 pCi/g by multiple recycling of the clean product through a standard mineral jig multiple times.⁸ The report does not contain the mass flows, and the separation efficiency cannot be determined. Jigging tests by Keane produced a fair degree of separation each pass: a feed containing 1.67 percent DU produced a clean product stream containing 0.49 percent DU and consisting of 66.1 percent of the feed (Reference 4). Keane repeated the same series of tests 6 years later under subcontract to ORNL with essentially the same results (Reference 5). Although these separations are significant, they do not even approach those required to permit unrestricted disposal of the material.

4. Shaking Table

This wet separation technique can only be used for material greater than 10-mesh. It can be used to separate DU fragments from sand and pebbles, but it is not useful for the bulk of the sand (Reference 4).

5. Static and Moving Belt Separations

These are wet separators that use either an inclined sluice or a moving belt on which the slurry moves downward, counter to the motion of the belt. A moderate separation was achieved with the -20-mesh size fraction. The clean product stream contained 0.16 percent DU, and the feed stream contained 0.29 percent DU (Reference 4).

6. Rotating Spiral Concentrator

This device consists of a disc with a peripheral rim with an axis of rotation inclined from the vertical. The disk has a hole in the center and a spiral riffle that decreases in curvature from the edge to the center. Heavy materials migrate to the center hole as concentrate. Performance generally improves if the coarse fractions are removed.

Tests indicate that significant concentration of DU is achievable (0.71 percent DU feed concentrated to 62.7 percent DU), but the tails stream accounted for 99.6 percent of the feed (Reference 4). In addition, the large quantity of water required for operation must be stored for analysis and possibly treated before disposal.

8J. W. Ayres, AWC, Inc., letter to A. A. Kahn, Martin Marietta Energy Systems, Inc., December 19, 1988.

7. Fluidized-Bed Tests

Elutriating bed tests using a feed with an activity of 26,300 pCi/gram yielded a clean product stream in the 2000 pCi/gram range that represented ~50 percent of the feed mass (Reference 3). Optimization of the test conditions would probably improve the results significantly.

8. Chemical Leaching Tests

Measures necessary to cleanse contaminated sand to 35 pCi/gram without wholesale dissolution of the sand have been developed (Reference 6). Strong oxidants (including three nitric acid washes with intermittent clean water washes and one intermittent drying step) are required to achieve a clean product that meets the <35 pCi/gram requirement for unrestricted disposal. Acid leaching was included in the economic analysis.

9. Screening Separation Tests

Several screening tests were performed in conjunction with sand sampling and size distribution surveys. These showed that 50 to 75 percent of the DU is contained in the +10-mesh fraction (which accounts for ~12 percent of the total quantity).

An additional concentration of DU was found in the fines (<60-mesh). Approximately 18 percent of the DU fed to a screen separator may be captured in the -60-mesh fraction. This fraction must be removed in any case because of the operational problems it causes with the air filters. These numbers indicate that screening is capable of removing as much as 90 percent of the DU in the coarse (+10-mesh) fraction and the fines (-60-mesh).

Bench-scale tests by Keane defined the conditions required for proper screening operation and the allowable mass flow rate as a function of screen size (Reference 5). These tests showed that moisture in excess of 2 percent caused poor screen performance. Because the target butt sand is frequently sprayed with water as a dust control measure, the moisture level of the sand will exceed the 2 percent limit, and a dryer will be required to make any screening operation effective.

SECTION III EVALUATION OF SAND/DU SEPARATION METHODS

A subjective summary of the various sand/DU separation methods is shown in Table 1. Each method is evaluated on a scale of 1 to 5 in each of the five performance categories shown. None of the physical separation methods can reduce the activity level to 35 pCi/gram. Despite the extremely low overall rating, chemical leaching is the only method evaluated that allows unrestricted disposal.

A. SYSTEMS EVALUATION FOR EGLIN AFB

The key to reducing disposal costs is reducing the volume of the waste. Systems considered for minimizing the amount of low-level waste considered in this study include:

1. Alternate catchment designs or catchment media that limit the production of low-level waste to that of the penetrators.
2. Sand/DU separation to reduce the activity of the sand to <35 pCi/gram.
3. Sand processing and reuse to limit the amount of low-level waste.
4. Operational changes to limit the amount of sand that must be periodically replaced.

The use of alternate catchment media is potentially cost-effective for new facilities but was not considered in this analysis because it is not a cost-effective replacement for the existing facility. As a result of the ranking exercise shown in Table 1, disposal costs were estimated for the following five options:

Option 1: Improved screening with sand recycle and on-site packaging.

Option 2: Same as Option 1 with DU fragment recycle.

Option 3: Same as Option 1 with wet separator derating fines.

Option 4: Same as Option 1 with chemical treatment for derating fines.

Option 5: Modified test butt; no sand processing.

TABLE 1. EVALUATION CATEGORIES

Separator Device	Test evaluation	Ruggedness/ simplicity	Cost/ Commercial Availability	Safety	Separation efficiency ^a	Overall Performance factor
Water medium separators						
Fluidized bed	b	4	2	3	3	72
Hydroclone		4	2	3	3	72
Jig	b,c	4	5	3	2	120
Spiral	c	4	3	3	3	103
Shaking table	c	4	5	3	2	120
High-gradient magnetic		2	1	2	2	8
Open-gradient magnetic		3	2	3	1	18
Chemical leaching	c	1	1	1	5	5
¹⁴ Dry separators						
High-gradient magnetic		1	1	2	2	4
Open-gradient magnetic	b,c	4	3	3	1	36
Electrostatic	c	3	3	2	2	36
Dry classifier		4	3	2	3	72
Sifting through screens	b	4	5	4	3	240

^aNo single device provides sufficient separation for derating sand except chemical leaching.

^bEvaluated in Phase 2 of current study.

^cEvaluated in earlier Air Force contract studies.

Each option is fully described in Volume III of this report, Economic Comparison of Depleted Uranium Disposal Options for the Eglin AFB Gun Test Facility. Options 2 and 3 contain features which have not proven to be feasible and which therefore cannot be fully implemented as described. Option 3 presumes derating of contaminated fines by a wet density separation. Phase 2 tests by Kahn, reported in Volume IV of this report, have shown that even the large degree of separation obtainable with wet separation methods is not sufficient to meet the requirements for unrestricted disposal. Option 2, in addition to DU fragment recycle, includes processing of the contaminated fines by an outside contractor.

For a number of reasons, this has proven to be a questionable operation and is not considered as a feasible alternative.

B. ECONOMIC COMPARISON OF OPTIONS

The life-cycle cost of each option was compared using guidelines provided in Air Force Regulation (AFR) 178-1 and Office of Management and Budget (OMB) Circular A-94 (References 7 and 8). Several of the assumptions used in the economic analysis are listed in Table 2. Detailed flow sheets, operational data, and cost data for each alternative are included in Volume III of this report.

TABLE 2. PARTIAL LIST OF DATA USED IN ECONOMIC ANALYSIS

GAU-8 firing rate (1979-88, rounds/year)	17,000
GAU-8 firing rate (projected, rounds/year)	70,000
Sand in test butt (yd)	400
Rounds fired between fragment removal operations	17,000
Rounds fired between fines removal operations	53,000
Low-level waste disposal charge (1989, \$/ft ³)	38
Low-level waste disposal charge (1990, \$/ft ³)	60
Low-level waste disposal charge (post-1990, \$/ft ³)	100
Low-level waste charge real escalation rate (%)	10
Low-level waste packaging (status quo, \$/ft ³)	33
Low-level waste packaging (alternates systems, \$/ft ³)	23
Low-level waste transportation (\$/ft ³)	4.1
Contract labor rate (\$/h)	47
Discount rate (%)	10

Technology-Dependent Cost Data

	Status Quo	Acid Leaching	Screening Reuse	Modified test butt
Capital (1989, \$ x 10 ³)	0	5600	600	420
Decommissioning (1989, \$ x 10 ³)	500	1500	500	500
Operation and Maintenance	a	a	a	a

*Basis for O&M costs is technology dependent. Detailed data are provided in Volume III.

C. NONECONOMIC COMPARISON OF SYSTEMS

Noneconomic factors such as technical feasibility, health, safety, and environmental risk; and complexity are each as important (if not more important) than economic considerations. Table 3 is a rating factor matrix similar to that used in the separation method evaluation. A geometric product is used rather than an arithmetic sum because each rating area is essential to the overall system acceptability (i.e., advantages in one area do not compensate for weaknesses in others).

1. Technical Feasibility

The status quo and the modified test butt systems are currently in use, thus clearly feasible. The screening/ reuse alternative involves drying and screening the sand/DU mixture. Both of these operations are well-established commercial procedures, but neither has been used for the present application. Acid leaching has been successfully proven at bench scale, and similar processes are used by U.S. Department of Energy (DOE) contractors to recover weapon-grade material from a variety of slag materials. Leaching is technically feasible.

2. Health, Safety, and Environmental Risk

These risks for the status quo and the screening/reuse systems are comparatively low because each (1) involves infrequent operator interaction with radioactive material, (2) avoids the use of water and thereby reduces the probability of soil or water contamination, and (3) uses simple, reliable processing schemes. The modified butt alternative is proven and simple, but operators must frequently handle and work in the immediate vicinity of low-level radioactive materials. Acid leaching is designed to dissolve the DU in highly corrosive solvents and therefore involves significantly more risk than the others.

TABLE 3. NONECONOMIC COMPARISON OF SAND/DU TREATMENT SYSTEM

System	Technical feasibility	x HSE ^a	x Complexity	Overall performance rating
Status Quo	5	5	4	100
Acid Leaching	4	1	1	4
Screening/Reuse	4	5	5	100
Modified Test Butt	5	3	4	60

^aHSE is health, safety, and environment.

3. Complexity

Sand/DU processing operations are intermittent and conducted by general laborers. The status quo and modified butt alternative requires off-site contractor support for a sand replacement operation. Equipment mobilization is expensive, and an off-site contractor adds to the administrative complexity. Reuse is relatively simple and eliminates the need for off-site contractor support to process and package the DU-contaminated sand. The acid-leaching process is very complex, involving at least 16 chemical processing steps.

SECTION IV CONCLUSIONS AND RECOMMENDATIONS

All of the above comparisons lead to the conclusion that the best available option is for the Air Force to dry, screen, and recycle the intermediate-sized uranium contaminated sand. Figure 1 is a flow sheet for the recommended process. Successful implementation of this system will save the Air Force several million dollars over the next 20 years. The \$600,000 capital cost will be recovered during the demonstration test because the volume of low-level waste generated during the sand replacement operation will be reduced by about 90 percent.

A. EQUIPMENT PROCUREMENT

Each of the various items of equipment required for the drying, screening, and recycling operation is commonly available in industry. The problem with assembling the equipment, if there is to be a problem, will occur at the interface between adjacent elements. For example, the outlet of the mass flow hopper must be the right size and at the correct elevation to empty into the variable rate feeder; the variable rate feeder must be properly fitted to the dryer, and so on throughout the entire system. For this reason, it is recommended that the equipment be procured as a system rather than as individual items. By following this approach, the Air Force will avoid the problems inherent with mating equipment built by various manufacturers. A suggested Request for Proposal (RFP) is presented in Appendix B.

Portions of two reports from K D Engineering Company, the subcontractor that performed the physical characterization studies and some of the physical separation studies, are contained in Appendix A (References 5).⁹

⁹J. M. Keane, K D Engineering, letter report to Oak Ridge Natl. Lab., Martin Marietta Energy Systems, Inc., July 1989.

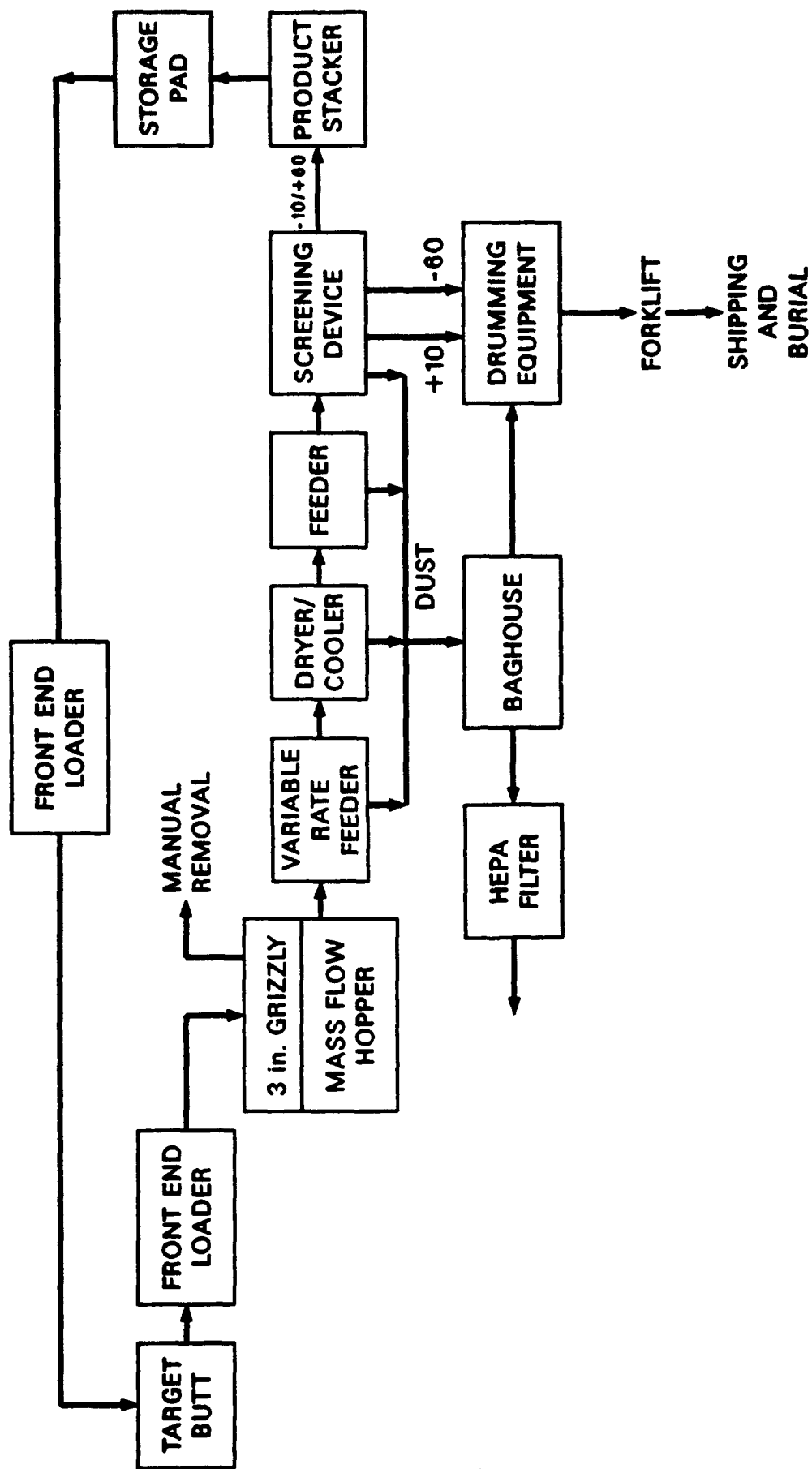


FIGURE 1. SAND-URANIUM SEPARATION/RECYCLE PROCESS FLOW SHEET

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1. C. W. Mallory et al., Alternatives for Disposal of Depleted Uranium Waste, AFATL-TR-85-78, Air Force Armament Laboratory, 1985.
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6. G. R. B. Elliott, DU Cleanup of Target Sand, LAC 83-11, Los Alamos Consultants, letter report to the Air Force Armaments Division, Eglin Air Force Base, 1983.
7. U.S. Air Force, Economic Analysis and Program Evaluation for Resource Management (Draft), AFR-178-1, January 7,
8. G. Shultz, letter to heads of executive departments, "Discount Rates to Be Used in Evaluating Time-Distributed Costs and Benefits," Circular No. A-94, March 27, 1972.

APPENDIX A

TARGET BUTT SAND PHYSICAL CHARACTERIZATION AND SCREENING STUDIES

A. PHYSICAL CHARACTERIZATION STUDIES AND EQUIPMENT RECOMMENDATIONS

1. Introduction

In January 1989, K D Engineering Co., Inc., was requested to submit a proposal to Oak Ridge National Laboratory, Martin Marietta Energy Systems, Inc. The subjects of this subcontract proposal were (1) the physical characterization of DU and associated munitions fragments in target butt sand, (2) amenability of fragmented DU to concentration by classical mineral beneficiation techniques, and (3) the generation of equipment recommendations for the removal of DU and the recycling of certain specific size fractions of sand back to the target butt.

The initial K D Engineering proposal was concerned with the generation of size distribution data, analytical information, and laboratory testing. On January 11, 1989, purchase order 394 TB663V was issued, and notification of shipment of the target butt sand sample was received on January 22, 1989.

In March 1989 the original project scope was increased to include development of preliminary engineering recommendations and equipment selection criteria based on the laboratory test work. Finally, the scope of work was again expanded in May of 1989 to include additional screen analysis work at various levels of target butt sand moisture content.

The final report encompassing all of the foregoing aspects of the project was submitted in June 1989. The project was concluded by returning all test products, screen fractions, and unused target butt sand to Eglin AFB, Florida.

2. Summary and Conclusions

The target butt sand sample submitted for investigation was characterized by the presence of more than 95 percent of the DU in the +1/4 inch fraction.¹⁰ Screening of dry and wet target

¹⁰The sample reported here may not be representative of the entire butt. The results of a somewhat more statistically valid analysis presented in Volume II, Section V.C and Appendix C, indicate that the total DU content of the +10 and the -60 fractions is about 80 percent.

butt sand at 1/4 inch. effectively removes DU penetrators and penetrator fragments, along with aluminum and plastic material, pebbles, and a small number of magnetic particles.

The target butt sand sample contained more than 20 percent by weight in the -60-mesh fraction. If the target butt sand is dry (<2.5 percent moisture), screening will remove a large portion of the -60-mesh material. However, if the target butt sand contains more than 2.5 percent moisture, agglomeration occurs, and the separation of -60-mesh material is not possible using conventional screening equipment.

The +1/4-inch fraction of target butt sand contained more than 50 percent DU by weight. The -1/4 inch by +10-mesh fraction assayed 0.25 percent total uranium. All of the fractions finer than 10-mesh assayed between 0.10 and 0.12 percent uranium. The -60-mesh fraction did not contain an upgraded quantity of DU.

A number of beneficiation methodologies were studied in an attempt to delist the target butt sand. The DU concentration goal for delisting is a content of 40 ppm (0.0040 percent) uranium or less. Dry magnetic separation, jigging, or rotating spiral concentration did not result in production of a delisted tailing product.

An equipment assemblage has been defined which will separate the coarsest screen fraction (+10-mesh) and the finest fraction (-60-mesh) from the target butt sand for disposal. The remaining -10-mesh by +60-mesh fraction would be recirculated to the target butt in combination with sized makeup sand. The equipment assemblage consists of a loader hopper, auger conveyor, dryer-cooler, transfer conveyor, multideck vibrating screen, product conveyor, and discard packaging apparatus. General equipment duty specifications are defined herein, and a partial list of vendors for the major equipment items has been developed.

3. Laboratory Test Work

Physical characterization of the target butt sand involved a number of laboratory experiments. These tests included as-received dry screen analyses, wet screen analyses of selected dry screen fractions to generate screening efficiency information, total uranium and carbonate-soluble uranium assays of selected screen fractions, and batch screen testing of target butt sand at several moisture levels. Experimental technique and test results are summarized in the following discussion.

a. Sample No. 1 - Size Distribution Information

The first target butt sample was subjected to several screen tests. The procedures associated with each of these studies along with pertinent data are detailed in the following discussions.

(1) Initial Dry Screening Procedure. A 50-kilogram sample was riffle-split from one of the two drums containing target butt sand. This 50-kilogram sample was treated according to the following procedure:

- A 16- by 24-inch Gilson Test-Master laboratory screen (Model TM-1) was equipped with 1/4 inch, 10-mesh, 20-mesh, 40-mesh, and 60-mesh removable laboratory screen decks.

- The entire 50-kilogram sample split was transferred to the top deck of the Gilson screen as rapidly as possible.

- The screen was allowed to operate for a period of 5 minutes, after which time the oversized fraction remaining on each screen deck was weighed.

- Each individual screen fraction was dried in its entirety.

- The dried +1/4 inch material was hand screened on a 3/8 inch sieve. The +3/8 inch and the -3/8 + 1/4 inch fractions generated by this procedure were further separated by hand into the following components:

- Depleted uranium
- Magnetic material
- Pebbles
- Aluminum and plastic fragments

- The dried fractions from the original screening procedure were weighed, and the percent moisture was calculated.

- An assay sample was procured from each of the dry screen analysis fractions. These samples were assayed for total uranium and carbonate soluble uranium. The analytical procedures used to determine total uranium and carbonate-soluble uranium are given in Section F. The total uranium content of the +3/8 inch and the -3/8 + 1/4 inch fractions was determined by direct weight.

• Another sample was procured from the dry screen fractions and was wet screened on 60-mesh. The fractions generated were dewatered, dried, and weighed. Minus 60-mesh material contained in each dry screen fraction was calculated.

(2) Percent Moisture Calculation and Results.
The results of the dry screen procedure detailed above are summarized in Table A-1.

An inspection of the foregoing tabulation reveals that the sample moisture content increased with decreasing particle size. The overall moisture content of the sample as tested was 1.72 percent.

The dry screen size distribution that resulted from the screening procedure described above is given in Table A-2. Perusal of this tabulation indicates that only 2.5 percent of the target butt sand reported to the -60-mesh fraction.

(3) Plus 1/4 inch Material Distribution. The size distributions and material types for the +3/8 inch, the 3/8 + 1/4 inch, and the combined +1/4 inch fractions are given in Table A-3.

An examination of this tabulation reveals that the DU content of the coarse fractions of target butt sand is 47 to 53 percent by weight. The other constituents in the coarse fraction of the target butt sand have much lower specific gravities than DU. Consequently, on a volumetric basis, the DU comprises -10 percent of the sample.

(4) Screening Efficiency at 60-mesh. The -60-mesh material produced by wet screening each of the dry screened oversized fractions is summarized in Table A-4. An inspection of this tabulation reveals that a considerable quantity of 60-mesh material was present in the dry screen fractions. A reconstituted wet screen analysis is given in Table A-5.

If 60-mesh screen efficiency is defined as the amount of 60-mesh material that reported to 60-mesh during dry screening (1260 grams) divided by the calculated amount of 60-mesh material in the sample (7163 grams), then the 60-mesh screen efficiency for Sample 1 calculates to 17.7 percent. Obviously, the screening technique used did not allow for a reasonable separation of -60-mesh material.

TABLE A-1. PERCENT MOISTURE CALCULATION, SAMPLE 1

Mesh size	As-received weight (g)	Dried weight (g)	Moisture (%)
+3/8 inc.	1,435	1,431	0.28
-3/8 + 1/4	524	523	0.19
-1/4/+10-mesh	2,432	2,402	1.24
-10/+20	10,303	10,154	1.47
-20/+40	23,985	23,555	1.83
-40/+60	10,819	10,602	2.05
-60	1,287	1,260	2.14

TABLE A-2. DRY SCREEN SIZE DISTRIBUTION, SAMPLE 1

Mesh size	Weight (g)	Weight (%)	Cumulative weight (%)
+3/8 in.	1,431	2.9	2.9
-3/8 + 1/4	523	1.0	3.9
-1/4/+10-mesh	2,402	4.8	8.7
-10/+20	10,154	20.3	29.0
20/+40	23,555	47.3	76.3
20/+60	10,602	21.2	97.5
-60	<u>1,260</u>	<u>2.5</u>	100.0
Total	49,927	100.0	

TABLE A-3. DISTRIBUTION OF VARIOUS PRODUCTS IN THE COARSE FRACTIONS OF TARGET BUTT SAND, SAMPLE 1

	Plus 3/8-in. Fraction		Minus 3/8 plus 1/4-in.		Total Fraction plus 1/4 in.	
	Weight (g)	Weight (%)	Weight (g)	Weight (%)	Weight (g)	Weight (%)
Pebbles	54.6	3.8	89.3	17.1	143.9	7.4
Aluminum	556.7	39.0	153.3	29.4	710.0	36.4
DU	760.1	53.3	245.6	47.1	1005.7	51.6
Magnetic	<u>55.6</u>	<u>3.9</u>	<u>33.5</u>	<u>6.4</u>	<u>89.1</u>	<u>4.6</u>
Total	1427.0	100.0	521.7	100.0	1948.7	100.0

TABLE A-4. CALCULATED SCREEN EFFICIENCY (RELATIVE TO 60-MESH), SAMPLE 1

Fraction	Weight (g)	60-Mesh Screen efficiency(%)
-1/4 in./+10 Washed oversize	570.89	93.8
-1/4 in./+10 Washed undersize	<u>37.70</u>	
Total	608.59	
-10/+20 Washed oversize	694.97	94.6
-10/+20 Washed undersize	<u>39.48</u>	
Total	734.45	
-20/+40 Washed oversize	636.96	90.1
-20/+40 Washed undersize	<u>70.13</u>	
Total	707.09	
-40/+60 Washed oversize	866.00	72.8
-40/+60 Washed undersize	<u>324.28</u>	
Total	1190.28	
-10/+60 Washed oversize	2197.93	83.5
-10/+60 Washed undersize	<u>433.89</u>	
Total	2631.82	

TABLE A-5. WET SCREEN SIZE DISTRIBUTION, SAMPLE 1

Mesh Size	Weight (g)	Weight (%)	Cumulative Weight (%)
+1/4	1,954	3.9	3.9
-1/4/+60	40,800	31.7	85.6
-60	<u>7,173</u>	<u>14.4</u>	100.0
Total	49,927	100.0	

60-Mesh Screen Efficiency = $1260^a / 7173 \times 100 + 17.7\%$

^aFrom Table A-2.

TABLE A-6. TOTAL AND CARBONATE-SOLUBLE URANIUM DISTRIBUTION, SAMPLE 1

Size Fraction	Weight (g)	Weight (%)	Total U (%)	Carb-sol U (%)	<u>Distribution</u>	
					Total U (%)	Carb-sol U (%)
+1/4 in.	1,954	3.9	51.6		94.7	
-1/4/+10-mesh	2,402	4.8	0.245	0.040	0.6	3.6
-10/+20	10,154	20.3	0.120	0.059	1.1	22.7
20/+40	23,555	47.3	0.107	0.050	2.4	44.8
40/+60	10,602	21.2	0.112	0.062	1.1	24.9
60	<u>1,260</u>	<u>2.5</u>	<u>0.122</u>	<u>0.086</u>	<u>0.1</u>	<u>4.0</u>
Total	49.927	100.0	2.126	0.055	100.0	100.0

(5) Total and Carbonate-Soluble Uranium Distribution. Total uranium and carbonate-soluble uranium analytical information is summarized in Table A-6.

As previously mentioned, the quantity of DU in the +1/4 inch material was calculated from direct weight of the constituents making up that fraction. Assay results reveal that all of the -10-mesh fractions contain -0.1 percent total uranium. The proportion of carbonate-soluble uranium to total uranium increases from -50 percent in the 10 to 60-mesh fraction to 67 percent in the -60-mesh fraction. There was no particular upgrading of the uranium content in the -60-mesh fraction of the target butt sand tested.

b. Sample No. 2 - Dry Screen Analyses

Since it was suspected that the screening technique used for Sample 1 resulted in overloading of the finer screen sizes, a modified technique was applied to Sample 2.

(1) Procedure. A modified procedure used for Sample 2 may be described as follows:

- The previously described Gilson Laboratory screening apparatus was equipped with 1/4 inch, 10-mesh, 20-mesh, 40-mesh, and 60-mesh screens.

- A 50-kilogram sample was riffle-split from the bulk target butt sand sample. The oversized material remaining on each screen deck was removed and the process was repeated until all the test material had been subjected to screening.

- Each screen fraction was weighed, dried, and weighed again.

• Size distributions and moisture content were calculated.

(2) Dry Screen Results. The results of the procedure described above are summarized in Table A-7.

An examination of the foregoing tabulation reveals that the moisture content of the target butt sand increased as particle size decreased. The overall moisture of the sample was noted to be 2.32 percent.

The modified screening procedure resulted in a much larger quantity of material reporting to the -60-mesh product, as detailed in Table A-8.

An examination of the foregoing tabulation reveals that the modified screening procedure resulted in -11.2 weight percent of the sample reporting to the -60-mesh fraction. It should be recalled that only 2.5 weight percent of the target butt sand material reported to the -60-mesh fraction by the procedure utilized for Sample No. 1.

(3) Material Distribution in +1/4 inch Fraction. As a check on the material distribution in the +1/4 inch fraction, this portion of Sample 2 was screened by hand on a 3/8 inch screen; then both the +3/8 inch fraction and the -3/8 + 1/4 inch fraction were separated by hand into four distinct materials: pebbles, aluminum and plastic, DU, and magnetic particles. This information is summarized in Table A-9.

A comparison of the foregoing tabulation with Table A-2 reveals a fairly close agreement between the size distribution of various materials contained in the +1/4 inch fraction of target butt sand. DU penetrators and penetrator fragments total ~51 percent of the +1/4 inch material by weight. Aluminum and plastic fragments are about 36 to 37 percent by weight. The remainder of the material in the coarse fraction of the target butt sand consists of rounded pebbles and magnetic munition fragments.

TABLE A-7. PERCENT MOISTURE CALCULATION, SAMPLE 2

Mesh Size	As-Received weight (g)	Dried weight (g)	Moisture (%)
+3/8 in.	2,101	2,092	0.43
-3/8 in./+1/4	696	690	0.87
-1/4/+10-mesh	3,200	3,157	1.36
-10/+20	11,712	11,482	2.00
-20/+40	24,838	24,280	2.30
-40/+60	10,051	9,795	2.61
-60	<u>6,714</u>	<u>6,472</u>	<u>3.73</u>
Total	59,312	57,968	2.32

TABLE A-8. DRY SCREEN SIZE DISTRIBUTION, SAMPLE 2

Mesh Size	Weight (g)	Weight (%)	Cumulative Weight (%)
+3/8 in.	2,092	3.61	3.61
-3/8/+1/4	690	1.19	4.80
-1/4/+10-mesh	3,157	5.45	10.25
-10/+20	11,482	19.81	30.06
20/+40	24,280	41.89	71.95
40/+60	9,795	16.90	88.85
-60	<u>6,472</u>	<u>11.15</u>	100.00
Total	57,968	100.00	

TABLE A-9. DISTRIBUTION OF VARIOUS PRODUCTS IN THE COARSE FRACTIONS OF TARGET BUTT SAND, SAMPLE 2

	Plus 3/8-in.		Minus 3/8 Plus 1/4-in.		Total Fraction Plus 1/4-in.	
	Weight (g)	Weight (%)	Weight (g)	Weight (%)	Weight (g)	Weight (%)
Pebbles	59.5	2.8	171.5	24.6	231.0	8.3
Aluminum	865.5	41.2	193.7	27.8	1059.2	37.9
DU	1127.8	53.7	302.1	43.4	1429.9	51.1
Magnetic	<u>48.6</u>	<u>2.3</u>	<u>28.9</u>	<u>4.2</u>	<u>77.5</u>	<u>2.7</u>
Total	2101.4	100.0	696.2	100.0	2797.6	100.0

TABLE A-10. PERCENT MOISTURE CALCULATION, SAMPLE 2

Mesh Size	As-Received weight (g)	Dried weight (g)	Moisture (%)
+1/4 in.	1,633	1,633	
-1/4/+10-mesh	1,925	1,911	0.73
-10/+20	6,530	6,480	0.77
-20/+40	19,320	19,136	0.96
-40/+60	9,560	9,453	1.13
-60	<u>8,005</u>	<u>7,609</u>	<u>5.20</u>
Total	46,973	46,222	1.62

c. Sample No. 3 - Size Distribution Information

The discrepancy in the weight of material in the -60-mesh fractions of Samples 1 and 2 dictated that a third check sample be subjected to a dry screen procedure, followed by wet screening on 60-mesh, of each of the retained fractions.

(1) Procedure. The procedure followed in this experiment is described below.

- A 50-kilogram sample of target butt sand was riffle-split from the shipping "drum.

- Approximately one-quarter of the sample was placed on the top screen of the Gilson screening apparatus described previously. Screening was conducted for 5 minutes; then the material retained on each screen panel was removed, and an additional one-quarter of the test sample was subjected to the same procedure. Each individual screen fraction was weighed, dried, and reweighed; and the individual percent moisture for each fraction was calculated.

- A portion of each oversized fraction was wet screened on a 60-mesh screen. Oversized and undersized portions were dewatered, dried, and weighed. The proportion of -60-mesh material contained in each oversized fraction was calculated.

(2) Percent Moisture and Dry Size Distribution. The percent moisture calculation for each of the screen fractions is given in Table A-10. An examination of this tabulation reveals that the moisture content of each screen fraction increases with decreasing size. The overall moisture calculated was 1.62 percent.

The dry screen distribution that results from the procedure described previously is given in Table A-11. An examination of this tabulation reveals that the size distribution for Sample 3 approaches the dry screen size distribution of Sample 2.

(3) Screening Efficiency at 60-mesh. Test data generated by the wet screening of each dry screen fraction on 60-mesh is summarized in Table A-12. An inspection of this tabulation reveals a high screening efficiency for this test sample.

TABLE A-11. DRY SCREEN SIZE DISTRIBUTION, SAMPLE 2

Mesh Size	Weight (g)	Weight (%)	Cumulative Weight (%)
+1/4 in.	1,633	3.5	
-1/4/+10-mesh	1,911	4.1	7.6
-10/+20	6,480	14.0	21.6
20/+40	19,136	41.4	63.0
-40/+60	9,453	20.5	93.5
-60	<u>7,609</u>	<u>16.5</u>	100.0
Total	46,222	100.0	

TABLE A-12. CALCULATED SCREEN EFFICIENCY (RELATIVE TO 60-MESH), SAMPLE 2

Fraction	Weight (g)	60-Mesh Screen Efficiency (%)
-1/4 in./+10 Washed oversize	979.00	98.0
-1/4 in./+10 Washed undersize	<u>20.00</u>	
Total	999.00	
-10/+20 Washed oversize	949.00	95.2
-10/+20 Washed undersize	<u>48.00</u>	
Total	997.00	
-20/+40 Washed oversize	953.00	95.2
-20/+40 Washed undersize	<u>45.00</u>	
Total	998.00	
-40/+60 Washed oversize	935.00	94.3
-40/+60 Washed undersize	<u>57.00</u>	
Total	992.00	
-10/+60 Washed oversize	3816.00	95.7
-10/+60 Washed undersize	<u>170.00</u>	
Total	3986.00	

TABLE A-13. WET SCREEN DISTRIBUTION, SAMPLE 2

Mesh Size	Weight (g)	Weight (%)	Cumulative Weight (%)
+1/4 in.	1,633	3.5	
-1/4/+60	35,231	76.3	79.8
-60	<u>9,353</u>	<u>20.2</u>	100.0
Total	46,222	100.0	

60-mesh Screen Efficiency = $7609^{\circ}/9358 \times 100 = 81.3\%$.

^aFrom Table A-11.

A reconstituted wet screen size distribution is given in Table A-13. An examination of this table reveals that the +1/4 inch fraction comprises ~3.5 weight percent of target butt sand. The 60-mesh fraction contains about 20.2 weight percent. The total screen efficiency relative to 60-mesh for Sample 3 calculates to 81.3 percent.

d. Sample No. 4 - Elevated Moisture Content Screening

Since handling of the target butt sand sometimes involves the addition of moisture for dust abatement, an experiment was conducted to determine the influence of moisture addition upon screen efficiency.

(1) Procedure. The test procedure used in this experiment is described below:

- Approximately 50 kg of target butt sand was riffle-split from the shipping container.

- The sample was placed in a small cement mixer, and 2 kg of water were added as a fine mist to the sample as it was rotating in the cement mixer.

- Approximately one-quarter of the sample was placed on the Gilson screening apparatus, and screening was conducted for 5 minute for each sample portion.

- At the end of the screening period, oversized material from each screen was removed. The finest screen decks were found to be blinded and were brushed with a stiff bristle brush before the next quarter of the sample was screened.

- Each screen fraction was weighed, dried, and reweighed; and the percent moisture" of each fraction was calculated.

A portion of each of the dried oversized fractions was wet screened on 60-mesh. Screen oversized and undersized fractions were dewatered, dried, and weighed; and the screening efficiency relative to 60-mesh was computed.

(2) Size Distribution Information. The percent moisture calculation was derived as mentioned previously and is given in Table A-14. An examination of this table and a comparison with preceding dry screening procedures reveals that the moisture addition resulted in severe blinding of the screen panels, particularly the finer sizes. The percent moisture contained in the sample calculated to 5.62 percent.

The actual particle size distribution that resulted from the screening procedure described is shown in Table A-15. An examination of this tabulation indicates that screening at 1/4 inch is still effective but that all other size fractions have been influenced by the complete agglomeration of the target butt sand.

(3) Screen Efficiency at 60-mesh. The individual wet screen oversized and undersized results are given in Table A-16. An examination of this tabulation indicates that screening efficiency relative to 60-mesh has severely degraded commencing on 10-mesh. This circumstance is indicative of the almost complete degree of agglomeration of the sample.

The reconstituted wet screen size distribution is given in Table A-17. This wet screen size distribution relatively coincides closely with previous wet screen size distributions. Because of the severe blinding that occurred, the 60-mesh screen efficiency computes to only 0.78 percent.

TABLE A-14. PERCENT MOISTURE CALCULATION, SAMPLE 3

Mesh Size	As-Received Weight (g)	Dried Weight (g)	Moisture (%)
+1/4 in.	2,185	2,157	1.30
-1/4/+10-mesh	18,171	16,891	7.58
-10/+20	23,362	22,156	5.44
-20/+40	6,533	6,362	2.69
-40/+60	303	295	2.71
-60	<u>87</u>	<u>83</u>	<u>4.82</u>
Total	50,641	47,944	5.62

TABLE A-15. DRY SCREEN SIZE DISTRIBUTION, SAMPLE 3

Mesh Size	Weight (g)	Weight (%)	Cumulative Weight (%)
+1/4 in.	2,157	4.5	
-1/4/+10-mesh	16,891	35.2	39.7
-10/+20	22,156	46.2	85.9
-20/+40	6,362	13.3	99.2
-40/+60	295	0.6	99.8
60	<u>83</u>	<u>0.2</u>	
Total	47,944	100.0	

TABLE A-16. WET SCREEN SIZE DISTRIBUTION, SAMPLE 3

Fraction	Weight (g)	60-mesh Screen Efficiency (%)
+1/4 in. Washed oversize	957.00	95.8
+1/4 in. Washed undersize	<u>42.00</u>	
Total	999.00	
-1/4/+10 Washed oversize	528.00	53.1
-1/4/+10 Washed undersize	<u>466.00</u>	
Total	994.00	
-10/+20 Washed oversize	895.00	89.9
-10/+20 Washed undersize	<u>101.00</u>	
Total	996.00	
-20/+40 Washed oversize	952.00	95.4
-20/+40 Washed undersize	<u>46.00</u>	
Total	998.00	
-40/+60 Washed oversize	265.00	89.8
-40/+60 Washed undersize	<u>30.00</u>	
Total	295.00	
-1/4/+60 Washed oversize	3597.00	84.0
-1/4/+60 Washed undersize	<u>685.00</u>	
Total	4282.00	

TABLE A-17. WET SCREEN SIZE DISTRIBUTION, SAMPLE 3

Mesh Size	Weight (g)	Weight (%)	Cumulative Weight (%)
+1/4 in.	2,066	4.3	
-1/4/+60	35,221	73.5	77.8
-60	<u>10.657</u>	<u>22.2</u>	100.0
Total	47,944	100.00	

60-Mesh screen efficiency = $83^{\circ}/10.657 \times 100 = 0-.78\%$.

^aFrom Table A-15.

4. Beneficiation Testing

The terms of the subcontract stipulated a number of beneficiation tests to be conducted on target butt sand. Individual test procedures, analytical information, and concentration results are given in the following paragraphs.

The main function of physical beneficiation testing was to demonstrate the possibility of derating specific fractions of target butt sand to a uranium content of 30 ppm (0.0030 weight percent) or less.

a. Magnetic Separation Testing

The contract agreement called for dry magnetic separation tests to determine the effectiveness of this method in separating uranium and ferriferous materials from the target butt sand.

(1) Procedure. A portion of the 10 by +60-mesh wet screen material from Sample 1 was thoroughly dried. This material was subjected to dry magnetic separation using a Carpc Laboratory Induced Roll Magnetic Separator. Test conditions were as follows:

- Sample A was subjected to dry magnetic separation at a splitter position midway between the magnetic and nonmagnetic streams. The electromagnet amperage was adjusted to 1.5 A, giving a magnetic field strength of ~5000 gauss. The feed rate through the magnetic field was regulated to ~50 g/m.

- Sample B was subjected to a procedure similar to that outlined above except that the magnetic field strength was increased to an amperage reading of 3.0 A, or ~10,000 gauss.

(2) Magnetic Separation Results. The experimental results from the above-described magnetic separation procedure are given in Table A-18. An examination of the magnetic separation data reveals that a slight concentration of both uranium and iron was produced by the technique and equipment employed. However, it is doubtful that this approach could produce a nonmagnetic product that would conform to the derating standard of <40 ppm uranium (0.0040 percent uranium by weight).

b. Jig Experiments

The contractual agreement also stipulated an attempt to produce a derated product by gravity concentration methods, including jigging. A description of this procedure and experimental results are given in the following paragraphs.

(1) Procedure. Individual wet screened oversized fractions were split from the material generated in the Sample 1 wet screen analysis test. Each of these fractions was subjected to jigging according to the following procedure:

- A Denver Equipment Company laboratory test jig equipped with a 1/4-inch hutch screen was bedded with 100 gram of 3/8-inch steel shot.

- The jig was filled with water and adjusted to operate at 120 strokes/minute.

- The individual test screen fraction being studied was slowly fed to the jig over a period of ~5 minute.

- At the termination of the experiment, the hutch product was combined with the material retained in the jig basket and designated as jig concentrate. The jig concentrate and tailing were dewatered, dried, weighed, and assayed for uranium content.

- Mass balance calculations were performed.

TABLE A-18.

TEST RESULTS - MAGNETIC SEPARATION

Product	Amps	Weight (g)	Weight (%)	Assays (%)		Percent Distribution	
				U	Fe	U	Fe
-10/+60 Magnetic	1.5	7.11	7.93	0.256	1.31	15.5	15.9
-10/+60 Nonmag.	1.5	<u>82.53</u>	<u>92.07</u>	<u>0.118</u>	<u>0.58</u>	84.5	84.1
Calculated Feed		89.64	100.00	0.129	0.67		
-10/+60 Magnetic	3.0	8.56	8.20	0.286	1.61	18.9	21.3
-10/+60 Nonmag.	3.0	<u>95.85</u>	<u>91.80</u>	<u>0.108</u>	<u>0.52</u>	81.1	78.7
Calculated Feed		104.41	100.00	0.122	0.61		

(2) Jigging Results. The results of the jig test are summarized in Table A-19. Considerable difficulty was encountered in preparing the jig concentrate materials for assay, particularly for the coarser size fractions. A "Shatter Box"-type pulverizer was found to be most effective in reducing the coarse uranium-bearing concentrate material to a size sufficiently fine to allow blending and production of an analytical sample. These difficulties were not apparent in preparation of the jig tailing assay sample. However, the pyrophoric nature of elemental uranium was evident when the tailing samples were pulverized.

An examination of the jigging test results reveals that uranium did tend to concentrate in the jig hutch product in the coarser size fractions. However, in order to derate the jig tailing, assays at least 20 times lower than the best attained (-20/+40 fraction) must be realized. It is doubtful that this decrease in uranium assay could be accomplished by jigging or any other classical gravity concentration method. Recovery by gravity concentration tends to be influenced by the size distribution. Materials finer than 60 to 100-mesh are not usually treatable by this technique. An examination of the -60-mesh data reveals that uranium recovery did decrease relative to the coarser fractions.

c. Rotating Spiral Concentrator Experiments

A common gravity concentration device used in amenability testing is the rotating spiral concentrator, sometimes called the Archimedes Spiral or the "Gold Wheel." This device is a disk fabricated of plastic or aluminum which contains an endless spiral ridge that starts at the outside lip of the device and terminates at a hole in the center. The device is equipped with a variable-speed-drive motor and a wash water header. In operation, heavy material rides up the spiral to the

TABLE A-19. TEST RESULTS - JIGGING

Size Fraction	Product	Weight (g)	Weight (%)	Assay (%) U	Content	Uranium Distribution (%)
-1/4 in./+10	Conc.	127.6	12.83	0.980	0.1257	53.4
	Tail	<u>866.8</u>	87.17	0.126	<u>0.1098</u>	46.6
	Calc. feed	994.4			0.2355	
-10/+20	Conc.	72.9	7.38	0.556	0.0410	35.5
	Tail	<u>913.8</u>	92.62	0.084	<u>0.0778</u>	64.5
	Calc. feed	986.7			0.1188	
-20/+40	Conc.	60.7	6.22	0.773	0.0481	43.7
	Tail	<u>915.3</u>	93.78	0.066	<u>0.0619</u>	56.3
	Calc. feed	976.0			0.1100	
-40/+60	Conc.	32.5	3.42	0.848	0.0290	25.0
	Tail	<u>918.4</u>	96.58	0.090	<u>0.0869</u>	75.0
	Calc. feed	950.9			0.1159	
-60	Conc.	21.9	2.45	0.775	0.0190	13.2
	Tail	<u>868.6</u>	97.55	0.128	<u>0.6249</u>	86.8
	Calc. feed	890.5			0.1439	

hole in the center of the rotating disk and is washed into a concentrate cup. Lighter material washes over the edge of the disk and reports to a tailings container. The target butt sand testing procedure utilizing this device and the results of that testing are given in the following paragraphs.

TABLE A-20. TEST RESULTS - ROTATING SPIRAL CONCENTRATOR

Size Fraction	Product	Weight (g)	Weight (%)	Assay (%) U	Content	Uranium Distribution (%)
-1/4 in./+10	Conc.	96.88	17.45	0.360	0.063	24.5
	Tail	<u>458.46</u>	82.55	0.235	<u>0.194</u>	75.5
	Conc. feed	555.34			0.257	
-10/+20	Conc.	9.09	11.36	0.310	0.035	26.3
	Tail	<u>657.53</u>	88.64	0.110	<u>0.098</u>	74.7
	Conc. feed	666.62			0.133	
-20/+40	Conc.	45.33	7.28	0.333	0.024	23.5
	Tail	<u>576.99</u>	92.72	0.084	<u>0.078</u>	76.5
	Conc. feed	622.32			0.102	
-40/+60	Conc.	17.41	4.03	0.700	0.028	23.0
	Tail	<u>840.59</u>	95.97	0.098	<u>0.094</u>	77.0
	Conc. feed	858.00			0.122	
-60	Conc.	8.15	3.61	0.402	0.015	11.7
	Tail	<u>217.71</u>	96.39	0.117	<u>0.113</u>	88.3
	Conc. feed	225.86			0.128	

(1) Procedure. The procedure used in this investigation is as follows:

- Portions of washed screen oversized material were obtained from the individual size fraction of Sample 1.

- The spiral concentrator was set in motion, and the flow of wash water to the "distribution header" was adjusted.

• The size fraction to be tested was slowly added to the bottom of the rotating spiral concentrator disk. Addition rate was ~100 g/min.

• The concentrator was allowed to operate until no further material reported to the concentrate cup. The test was then terminated, and products were dewatered, dried, weighed, and assayed for total uranium. Sample preparation difficulties described previously were also encountered with the concentrate material produced by the rotating spiral device.

(2) Rotating Spiral Concentrator Results. A summary of the test results produced by the rotating spiral concentrator is contained in Table A-20. An examination of the rotating spiral concentrator data reveals that this device did not yield a sufficiently high uranium recovery to produce a derated tailing product. To generate a material that can be derated (contains <0.0040 percent uranium by weight), a tailing assay must be produced which contains 20 times less uranium than the best results of the test work. It is doubtful that the concentrating device studied could produce a tailing product having this extremely low uranium content.

5. Target Butt Sand Treatment

The size distribution information, analytical work, and beneficiation procedures detailed previously point to a methodology for routine treatment of target butt sand. At present, target butt sand contains ~20 weight percent -60-mesh material. Microscopic examination of this material reveals that most of the sand grains are rounded and are not the result of munitions impact. This indicates that 50- or -60-mesh material should be eliminated from the present target butt sand by screening. Replacement sand with a size distribution of -10-mesh by +50 or 60-mesh should replace the material removed. Additionally, all +1/4-inch munitions fragments and pebbles should be removed from the material presently in the target butt. An equipment assemblage to accomplish this task is discussed in the following paragraphs and in Appendix B.

a. General Criteria

Discussions with personnel from Martin Marietta Energy Systems have been conducted to define target butt sand treatment philosophy and criteria. Briefly, these discussions resulted in the establishment of a desired system throughput rate of 12,000 kg/h for the removal of +1/4-inch material and, if possible, the concurrent capability of producing 1,000 kg/h of -60-mesh undersized material.

It is desired to combine the +1/4-inch material or +10-mesh fraction with the -60-mesh fraction and route this combination directly into drums for disposal. The -10-mesh by +50 or 60-mesh material would be recycled to the target butt.

Dust abatement procedures in use may raise the moisture content of the target butt sand to the 4 to 5 percent moisture range. Laboratory testing has indicated that the +1/4-inch fraction can be successfully separated from wet target butt sand. However, all other mesh sizes below -10-mesh tend to agglomerate and blind individual screen panels. Consequently, an equipment assemblage is needed to contend with the stipulation that products for disposal must be almost completely dry. General engineering criteria for this equipment assemblage are given in the following discussion.

b. Sand Treatment Equipment Items

Engineering design work had not been completed relative to the equipment assemblage to treat target butt sand. The information given below is preliminary and provides general design criteria for the detailed engineering design.

(1) Sand Hopper. A receiving hopper for target butt sand must be designed to accommodate both the desired throughput and the capacity of the front-end loader bucket currently in use. Generally, this sand hopper should be sized to easily contain two full loader buckets and should be equipped with appropriate sloped sides to prevent and contain spills. The empty hopper should be readily movable by the front-end loader.

(2) Auger Feeder. A variable-speed auger feeder designed for quick and easy cleanout would discharge the hopper at a rate commensurate with desired throughput. This auger feeder must be designed to accept wet target butt sand along with angular aluminum and DU fragments. The auger flights should be spaced so that full length DU penetrators and large pieces of aluminum wind screen can be readily transported. The auger should be equipped with a variable-speed drive and would attach directly to the bottom of the hopper and terminate at an elevation suitable for feeding either a dryer or the vibrating screen apparatus.

(3) Indirect Rotary Dryer-Cooler. A number of configurations exist in the target butt sand processing flow sheet for an indirect dryer-cooler apparatus. If the entire quantity of target butt sand is to be dried before screening, an indirect dryer capable of an effective heat input of ~4 million Btu/h should be specified. The dryer can be heated either by combustion gases or an electric mantle. The material discharged from the dryer must be cooled to 100° to 125°F. The heat removal requirement is estimated at 1.5 to 2.0 million Btu/h. If the

dryer is to be used only for material to be discarded, then heat input and cooling requirements are much reduced. The dryer capacity could be reduced to ~0.5 million Btu/h and the cooler requirement could be reduced to ~100,000 Btu/h.

The recommended dryer would be a rotary indirect-fired device, with the DU and sand passing through an internal stainless steel tube. Airflow to the internal tube would be regulated by means of a fan and damper combination associated with the dust-collecting system. Part of the metallic uranium present in the target butt sand will undoubtedly oxidize when heated in the presence of air. However, the heat of reaction caused by uranium oxidation will contribute little to the sensible heat in the system. (Note: Subsequent discussions have indicated that a direct-fired dryer will be substantially less expensive and equally suitable.)

(4) Transfer Conveyor. A transfer conveyor between the cooler and the screening device may be necessary depending on equipment layout. This transfer conveyor should be of the same general size as the auger feeder but need not be equipped with a variable-speed drive.

(5) Screening Device. Because of the nature of the target butt sand, a screening device having the capability for easy removal and modification of screen size openings is recommended. These screening devices can be circular, square, or rectangular in shape. The preferred unit would be fully enclosed, and each screen deck would be equipped with a separate discharge nozzle. Rotary screening motion is imparted to the stack of screens through a motor eccentric arrangement.

A properly selected screening device of this type imparts very little vibratory motion to its associated support structure. In addition, this screen must be sized to provide the desired throughput and also be readily portable using the front-end loader or a medium size forklift. A screen that has individual screen panels of 20 to 25 ft² in area has been selected for preliminary equipment sizing requirements.

(6) Dust Abatement. A multiple-pickup baghouse has been selected to provide dust abatement requirements. This unit will handle the dust-laden discharge from the dryer and cooler and will also provide for dust abatement through pickup points at conveyor discharge positions and at the top of the screening device. The size of the dust collection system depends on the particular equipment configuration selected for target butt sand treatment. Required capacity could vary between 800 and 9000 actual cubic feet per minute. (Note: The direct-fired dryer will increase the required capacity of the baghouse.)

The dust-collecting system must be oriented so that the discharge from the baghouse can be readily conveyed to combine with the screen undersized discharge fraction. The induced draft fan required to operate the baghouse and provide a positive airflow through the dryer, cooler, and other dust producing transfer points must be sized to provide adequate draft as the filter media in the baghouse becomes loaded with dust, discharges, and then becomes loaded again.

(7) Product Stacker. The material to be recycled to the target butt (assumed to be the -10-mesh by +60-mesh fraction for this discussion) must be removed from the immediate area of the screening device at the same rate that the fractions are generated. A product conveyor and a stacker combination are envisioned.

This conveyor may be an enclosed belt conveyor or an appropriately sized auger conveyor. It is envisioned that the stacker will have a multiple-positioning capability so that the entire quantity of sand in the target butt can be stacked on a nearby concrete pad before being recycled into the target butt. Additionally, the conveyor-stacker must also have the capability of being easily moved and stored by the loader or a medium-size forklift.

(8) Discard Product Handling. The oversized and undersized material to be discarded will be combined immediately upon discharge from the specific screen panel or bottom screen tray and routed directly into drums, which will eventually be sealed for disposal. Each drum will rest upon a digital weighing device with associated roller conveyor so that the screen operator can fill the drum, note its weight, and replace a filled drum with an empty drum in a smooth, continuous operation. Dust abatement will be provided in the area through pickup points that will connect with the facility baghouse dust collector.

Usually in specialized facilities of the type envisioned for target butt sand treatment, the process selection does not cause problems. However, the design of material transport equipment and the interconnections between each unit operation can present process bottlenecks if sufficient thought is not given to this aspect of the process. The major equipment items, -dryer-cooler, screen, baghouse, and drumming equipment - can be specified and purchased in conformance with an existing manufacturer's design. However, the material transport equipment, hopper, feed auger, transfer conveyor, and product conveyor-stacker must be individually designed, with particular attention given to dust abatement and material transport requirements. Additionally, these devices must be designed for ease of assembly, disassembly, cleanout, movement, and storage.

6. Prior Studies

It is known that a portion of the DU present in the sand sample is in the form of uranium oxides. This is evidenced by visual inspection of larger DU fragments, which are usually coated with a yellow film of uranium trioxide. It would be most interesting to determine the amount of uranium oxidation that has taken place in each screen size distribution. To this end, a special analytical procedure was developed to determine hexavalent uranium in the presence of metallic uranium or other lower uranium oxides. We first contacted Union Carbide at Oak Ridge, Tennessee, and were informed that they were not aware of a method that could be used to determine uranium oxide in the presence of metallic uranium. A search of the literature revealed that uranium in its highest valence state (hexavalent) oxide, UO_3 , is soluble in neutral sodium carbonate solution, while elemental uranium and/or uranium dioxide, UO_2 , is insoluble in this lixiviant. Based on this information, an analytical method was developed which would allow the separate determination of hexavalent uranium.

a. Soluble (Hexavalent) Uranium Analytical Procedure

This procedure depends on the solubility of hexavalent oxides of uranium in solutions of sodium carbonate-bicarbonate and the relative insolubility of uranium metal in this reagent. In this particular application, quadrivalent oxides, if present, would not be solubilized by the reagent.

Reagents: Sodium carbonate, 5 percent in deionized H_2O .
Sulfuric acid, 1:1 with deionized H_2O .

Procedure: Transfer the weighed sample to an appropriately sized beaker and add a minimum of 50 milliliters of the 5 percent Na_2CO_3 solution (for large samples, add a volume equal to 10 times the sample weight). Adjust the PH of the solution to $7 + 0.5$ with 1:1 H_2SO_4 . Leach the sample for 2 hours at $-80^\circ C$ with agitation. Add acid as required to maintain the PH in the required range. Filter the sample (Whatman 40 or similar) and wash once with Na_2CO_3 solution adjusted to PH 7 with H_2SO_4 , wash three times with deionized H_2O . Transfer the filtrate to an appropriate volumetric flask, allow to cool to room temperature, and dilute to volume. Determine the uranium content of the solution by any acceptable method (inductively coupled plasma, atomic emission spectrometer, volumetric, colorimetric, or fluorimetric). The method used is the determining factor in the choice of sample size and dilution.

b. Total Uranium Analytical Procedure

Reagents: Hydrochloric acid
 Nitric acid
 Sulfuric acid
 Hydrofluoric acid

Procedure: Digest the sample to be analyzed with mixed acids. For samples of 5 grams or less, use 10 milliliters each of HCl and HNO₃, 3 milliliters of H₂SO₄, and 2 milliliters of HF. Use proportionately more acids for larger samples. Heat to incipient dryness, cool, wash the sides of the beaker with about 25 milliliters H₂O, add 10 milliliters HNO₃, and bring to a boil for 5 minutes. Filter (using a Whatman 40) and wash six to eight times with deionized H₂O. Receive the filtrate in an appropriate volumetric flask. Cool to room temperature and dilute to volume. Proceed with the determination of uranium in the solution by any appropriate method.

Note: The use of perchloric acid is not recommended. In the presence of appreciable metallic uranium, a violent reaction may occur.

When analyzing coarser screen sizes having metallic DU present, the entire sample should be decomposed instead of attempting to split the sample to a smaller size. It is felt that this procedure improves analytical accuracy.

B. SUPPLEMENTARY SCREENING DATA

1. Summary And Conclusions

Individual test data sheets outlining the screen analysis results from both dry and wet screening procedures are included here (see Tables A-21 to A-24). An examination of this information reveals that severe screen blinding of the finer screen sizes occurs at moisture levels in excess of 2 weight percent.

TABLE A-21. SAMPLE 1 - 0% MOISTURE

Wet Screen Analyses of Gilson Fractions			
Gilson Screen Results		Calc Actual Size Distribution	
Mesh	Weight (g)	Weight (g)	Weight (%)
+1/4	2,174	1,839.2	4.3
+10	1,576	1,678.5	3.9
+20	4,989	4,670.9	10.9
+40	14,700	13,323.3	31.0
+60	8,020	8,132.4	18.9
-60	11,513	13,327.7	31.0
Total	42,972	42,972.0	100.0

Wet Screen Analyses of Gilson Fractions			
Plus 1/4 in.		Plus 20-Mesh	
Mesh	Weight (g)	Weight (g)	Weight (%)
+1/4	1,835.0	913.8	91.8
+10	250.4	53.3	5.4
+20	3.7	3.0	0.3
+40	7.6	25.2	2.5
+60	11.1	995.3	100.0
-60	59.3		
Total	2,167.1		

Wet Screen Analyses of Gilson Fractions			
Plus 40-Mesh		Plus 60-Mesh	
Weight (g)	Weight (%)	Weight (g)	Weight (%)
878.9	88.7	873.1	88.7
66.6	6.7	111.7	11.3
45.9	4.6	984.8	100.0
991.4	100.0		

TABLE A-22. SAMPLE 2 - 2% MOISTURE

<u>Gilson Screen Results</u>			<u>Calc Actual Size Distribution</u>		
Mesh	Weight (g)	Weight (%)	Mesh	Weight (g)	Weight (%)
+1/4	1,829	4.3	+1/4	1,618.7	3.8
+10	1,670	3.9	+10	1,596.0	3.7
+20	5,843	13.7	+20	4,807.3	11.3
+40	16,435	38.5	+40	13,654.7	31.9
+60	8,144	19.0	+60	8,144.5	19.1
-60	8,820	20.6	-60	12,919.8	30.2
Total	42,741	100.0	Total	42,741.0	100.0

Wet Screen Analyses of Gilson Fractions

<u>Plus 1/4 in.</u>			<u>Plus 20-Mesh</u>			<u>Plus 40-Mesh</u>			<u>Plus 60-Mesh</u>		
Mesh	Weight (g)	Weight (%)	Weight (g)	Weight (%)	Weight (g)	Weight (g)	Weight (%)	Weight (g)	Weight (g)	Weight (%)	Weight (%)
+1/4	1,616.0	88.5	854.0	85.6	802.6	80.7	793.8	79.8	782.7	78.8	
+10	165.9	9.1	53.6	5.4	87.6	8.8	97.4	9.8	210.2	21.2	
+20	1.7	0.1	13.3	1.3	15.2	1.5	103.7	10.4			
+40	4.0	0.2	14.1	1.4	89.7	9.0					
+60	6.2	0.3	62.5	6.3							
-60	33.3	1.8									
Total	1,827.1	100.0	997.5	100.0	995.1	100.0	994.9	100.0	992.9	100.0	

TABLE A-23. SAMPLE 3 - 2% MOISTURE

<u>Gilson Screen Results</u>			<u>Calc Actual Size Distribution</u>		
Mesh	Weight (g)	Weight (%)	Mesh	Weight (g)	Weight (%)
+1/4	1,279	3.0	+1/4	1,057.7	2.5
+10	3,790	8.8	+10	1,735.7	4.0
+20	10,151	23.5	+20	5,470.5	12.7
+40	25,156	58.3	+40	14,562.3	33.7
+60	2,060	4.8	+60	8,020.8	18.6
-60	703	1.6	-60	12,292.0	28.5
Total	43,139	100.0	Total	43,139.0	100.0

44

<u>Wet Screen Analyses of Gilson Fractions</u>										
Mesh	Plus 1/4 in. Weight (g)	Weight (%)	Plus 10-Mesh Weight (g)	Weight (%)	Plus 20-Mesh Weight (g)	Weight (%)	Plus 40-Mesh Weight (g)	Weight (%)	Plus 60-Mesh Weight (g)	Weight (%)
+1/4	1,057.6	82.7	400.3	40.7	487.4	49.1	457.0	47.2	595.7	60.2
+10	192.7	15.1	126.2	12.8	232.6	23.4	234.7	24.2	393.7	39.8
+20	1.5	0.1	80.6	8.2	40.6	4.1	276.3	28.6	989.4	100.0
+40	2.5	0.2	71.1	7.2	232.2	23.4	968.0	100.0		
+60	3.7	0.3	306.4	31.1	992.8	100.0				
-60	20.9	1.6	984.6	100.0						
Total	1,278.9	100.0								

TABLE A-24. SAMPLE 2 - 6% MOISTURE

<u>Gilson Screen Results</u>			<u>Calc Actual Size Distribution</u>		
Mesh	Weight (g)	Weight (%)	Mesh	Weight (g)	Weight (%)
+1/4	2,248	5.3	+1/4	1,915.3	4.5
+10	14,643	34.1	+10	1,627.1	3.8
+20	21,143	49.2	+20	4,946.4	11.5
+40	4,638	10.8	+40	13,582.6	31.6
+60	188	0.4	+60	7,661.8	17.8
-60	97	0.2	-60	13,222.8	30.8
Total	42,956	100.0	Total	42,956.0	100.0

<u>Wet Screen Analyses of Gilson Fractions</u>										
Mesh	Plus 1/4 in. Weight (g)	(%)	Plus 10-Mesh Weight (g)	(%)	Plus 20-Mesh Weight (g)	(%)	Plus 40-Mesh Weight (g)	(%)	Plus 60-Mesh Weight (g)	(%)
+1/4	1,919.1	85.2								
+10	236.0	10.5	93.7	9.5						
+20	4.5	0.2	193.6	19.6	95.2	9.8				
+40	6.3	0.3	102.6	10.4	438.2	44.9	548.8	55.2		
+60	12.5	0.5	120.1	12.1	197.2	20.2	306.8	30.8	175.4	95.5
-60	74.5	3.3	479.1	48.4	245.1	25.1	139.0	14.0	8.2	4.5
Total	2,252.9	100.0	989.1	100.0	975.7	100.0	994.6	100.0	183.6	100.0

Screen efficiency information is presented for each mesh size tested in Table A-25. An examination of this tabulation reveals that blinding of the 60-mesh screen began to occur at the 2 percent moisture level. Severe blinding of both 40 and 60-mesh screen decks was noted at the 4 percent moisture level. At the 6 percent moisture level, blinding had progressed to include the 20, 40, and 60-mesh screens.

TABLE A-25. SCREENING EFFICIENCY BY MESH SIZE

Screen Size	Moisture in Samples (%)			
	0	2	4	6
1/4 in.	99.2	99.5	99.5	99.2
10-mesh	99.4	99.3	94.4	66.1
20-mesh	98.4	96.2	80.1	14.3
40-mesh	91.0	80.5	13.6	1.4
60-mesh	86.4	68.3	5.7	0.7

An examination will also indicate that very high screen efficiencies were tested for the 1/4 inch screen at all moisture levels tested. This indicates that the +1/4 inch material can be efficiently removed from the target butt sand at moisture contents as high as 6 percent, even though most of the finer screens will be blinded at these higher moisture levels.

2. Procedure

The screening procedure used for this series of tests is described in the following paragraphs.

A quantity of target butt sand was procured from the shipping drum and divided into four portions, each weighing ~43 kilograms. Each sample was dried for a period of 24 hours at ~1050C.

The first sample (Sample 1) was completely free of moisture and was treated according to the following procedure:

- A 5 to 6 kilogram portion of the sample was placed on the top screen of a Gilson screening apparatus, which was equipped with a nest of 18- by 24 inch rectangular screen decks.

- The screen was operated for 1.5 minutes for each 5- to 6-kg sample portion.

- At the end of the screening period, the material retained on each deck was removed and stored in separate containers.

• When the entire test sample had been subjected to screening, the material retained on each screen deck was weighed.

A portion of the material retained on each screen fraction was subjected to wet screening through a nest of test sieves having the same openings as the Gilson apparatus. Each screen fraction from wet screening was filtered, dried, and weighed.

A second sample (Sample 2) was contacted with 860 milliliters water in a small rotating mixing device, thereby producing a test material having 2 percent moisture by weight. The identical screening procedure previously detailed for Sample 1 was used to determine screening characteristics and screen efficiency.

A procedure similar to that detailed for Sample 2 was used for a third sample (Sample 3) except that the sample was contacted with 1,720 milliliters water, giving a screen feed material containing 4.0 percent moisture.

A procedure similar to that detailed for Sample 2 was used for a fourth sample (Sample 4) except that 2580 milliliters of water was added to the dry sample before screening. This procedure produced a screen feed material containing 6.0 percent moisture.

The intent of the foregoing procedure was to develop screening characteristics for target butt sand samples having 0, 2, 4, and 6 percent moisture by weight.

APPENDIX B
SUGGESTED RFP FOR SAND/DEPLETED URANIUM SCREENING AND RECYCLE

A. PURPOSE

The purpose of this request is to solicit proposals for the design, fabrication, test, and initial installation of equipment to separate DU fragments from sand.

B. BACKGROUND

As part of an ongoing quality assurance program, Air Force ammunition from storage is sampled periodically for test firing to assure that it is in field-ready condition. One segment of this operation, at Eglin AFB, provides for test of the Air Force Gun, Automatic Utility-8 (GAU-8), which fires 30-mm armor-piercing-incendiary (API) ammunition, the primary constituent of which is depleted uranium (DU). The GAU-8 is a seven-barreled Gatlin-style gun capable of firing 4200 rounds/minute (600 rounds/minute through each barrel). The test facility is arranged so that the projectiles are fired through an open door in the building that houses the gun into a dampened sand butt housed in a target building about 100 feet away.

Upon impact, portions of the DU projectiles spall off, and the fine particles ignite spontaneously. The rest of the DU slug remains essentially intact and buries itself in the sand. A substantial amount of sand is fractured on impact, and fine dust is produced.

When the amount of DU and fine dust reach a certain level, they must be removed to prevent ricochet and excessive dusting problems. In the past, all the materials from the target butt (sand, DU fragments, fine dust, etc.) have been placed in 55 gallon drums and disposed of as low-level radioactive waste. As part of an effort to reduce the disposal costs, the Oak Ridge National Laboratory (ORNL) was requested to evaluate alternate catchment media and DU separation technologies.

The system selected for implementation is shown schematically in the attached figure (Figure B-1), sand-uranium separation/recycle process flow sheet. The system is designed to separate the coarse material (+10-mesh) and the fines (-60-mesh) from the intermediate fractions. The intermediate fractions are returned to the target butt, while the oversized and undersized material is placed in drums for disposal.

The sand/uranium mixture must be dried to a maximum moisture content of 2 percent prior to the screening operation to facilitate efficient removal of the fines. The separated fractions (i.e., the +10 and -60 portions) must be kept dry to assure safe storage.

C. FUNCTIONAL SPECIFICATIONS

1. Overall System

The system shall be designed for a nominal throughput of 5 yd³/hour (13,500 lb/hour) of a sand/uranium mixture, as described in Table B-1.

The system, beginning at the inlet to the variable rate feeder, shall be designed to operate under negative air pressure to prevent the escape of dust during the operation.

2. System Components

Specifications for individual equipment items are listed below.

a. Hopper

The hopper shall have a minimum capacity of 5 yd³. It shall be designed to accept a load delivered by a front-end loader with a 2.5-yd³ bucket. A 3-inch-square grizzly shall be installed at the top of the hopper to prevent grossly oversized pieces of material from entering the system. A means of personnel access to the grizzly shall be provided to facilitate manual removal of the oversized pieces.

The hopper shall be designed to promote mass-type flow (i.e., prevent bridging and/or rat-holing). The hopper discharge shall be designed to feed directly to the inlet of the variable rate feeder.

b. Variable Rate Feeder

The variable rate feeder shall be designed to accept the sand/uranium mixture directly from the hopper and transfer it to the dryer inlet. The construction of the feeder shall take account of the irregular nature of the material being transported and shall provide easy access for cleanout. It shall be designed to operate under negative pressure to prevent the escape of dust during operation. The discharge end of the variable rate feeder shall be designed to empty directly into the dryer.

The variable rate feeder shall have a nominal transport capacity of 5 yd³/hour with a turndown of at least 5.

c. Dryer/Cooler

The dryer shall be designed for a nominal throughput of 5 yd³/hour. The maximum initial moisture content of the sand/DU mixture is 7 percent. The probable initial moisture content is 5 percent + 1 percent. The maximum final moisture content shall be 2 percent. The dryer shall be designed to operate under negative pressure to prevent the escape of dust during operation. The dryer shall be designed to discharge directly to the feeder. Propane fuel for heating can be supplied if required.

d. Feeder

The feeder shall be designed to accept material directly from the discharge end of the dryer. The feeder shall have a nominal capacity of 5 yd³/hour and shall be designed to operate under negative pressure to prevent the escape of dust during operation. The construction of the feeder shall take into account the irregular nature of the material being transported and shall provide easy access for cleanout.

The feeder shall be designed to discharge directly to the screening device.

e. Screening Device

The screening device shall be designed to accept the material directly from the feeder. It shall be designed to separate the material into three categories: coarse material greater than 10-mesh, fine material smaller than 60-mesh, intermediate material less than 10-mesh and greater than 60-mesh. The coarse material and fine material may be recombined after separation from the intermediate material. The combined fractions shall be fed to the drumming equipment for loading into 55-gallon drums. The intermediate fraction shall be delivered to the product stacker. The screening device shall have a nominal capacity of 5 yd³/hour and shall be designed to operate under negative pressure to prevent the escape of dust during operation.

f. Baghouse and HEPA Filter

The baghouse shall be designed to remove the particulate matter from the bleed air that has been collected from the other components in the process line. The fan shall have head/flow capacity sufficient to develop and maintain negative pressure in each of the process components where it is required to prevent dusting. The ducting between the various components and the baghouse shall be designed to maintain particulates in suspension and not provide areas for unwanted accumulations.

Construction of the baghouse shall conform to good engineering practice and shall not allow any bypass flow.

Provision shall be made to transfer the collected particulate material to 55-gallon drums. It is desirable to mix the baghouse material with the oversized and undersized material derived in the screening operations.

A full-capacity HEPA filter shall be installed to prevent particulate discharge to the atmosphere in the event of incomplete filtration in the baghouse or a bag failure. The HEPA filter shall have an efficiency of not less than 99.97 percent when tested with 0.3-mm dioctyl-phthalate particles.

g. Product Stacker

The product stacker shall be designed to receive the intermediate (-10, +60) material from the screening device and convey it to an adjacent pad for storage until the entire target butt inventory has been processed. The approximate volume of the material to be stacked is 300 yd³.

h. Drumming Equipment

The drumming equipment shall be designed to facilitate the filling and transport of 55-gallon drums to and from the fill station. An operator-supplied forklift will be available to deliver and remove the drums.

D. SUGGESTED SUPPLIERS OF SAND/DU SEPARATION EQUIPMENT

Table B-2 contains the names and addresses of various companies that may be capable of supplying the equipment assemblage. The list does not necessarily include all possible suppliers.

TABLE B-1. DESCRIPTION OF SAND/DU MIXTURE

Moisture content 7 percent maximum, 5 percent + 1 percent
probable Volume per target butt: 400 yd³

Size distribution:

Mesh	Weight (%)
1/4	4
+10, +60	4
-10, +60	42
-60	30

**TABLE B-2. SUGGESTED SUPPLIERS OF SAND/DU SEPARATION
EQUIPMENT**

1. **Boliden Allis, Inc.**
Attn: W. J. Brewer
2255 South Wadsworth Blvd.
Suite 109
Lakewood, Colorado 80227
(303) 989-0754
2. **Vulcan Iron Works, Inc.**
Attn: John S. Jones
1050 United Penn Bank Bldg.
Wilkes-Barre, Pennsylvania 18701
(717) 882-2161
3. **Custom Equipment Corporation**
Attn: Bud Gale
350 West 300 South
Salt Lake City, Utah 84101
(801) 533-8557
4. **C-E Raymond**
Attn: Larry Morton
Combustion Engineering
1200 Ashwood Parkway, N.E.
Suite 510
Atlanta, Georgia 30338
(404) 394-2616
5. **E-Con, Inc.**
Attn: C. F. Addams
125 Powers Ferry Road
Marietta, Georgia 30067
(404) 977-7725
6. **Adams Brothers, Inc.**
Attn: Malcom Marsh
750 Eleventh Street N.W.
Atlanta, Georgia 30318
(404) 872-8881
7. **Airsystem Sales, Inc.**
Attn: Joe Connolly
277 Wilson Pike Circle
Suite 110
P.O. Box 1948
Brentwood, Tennessee 37024
(615) 373-0039

TABLE B-2 (CONCLUDED)

8. K D Engineering Co., Inc.
Attn: Joseph Keane
1844 W. Grant Road
Suite 106
Tucson, Arizona 85745
(602) 882-5141

9. Mechanical Contractors, Inc.
Attn: Robert Hoffman
602 Sand Bar Ferry Road
Augusta, Georgia 30901
(404) 722-1223

The following were bidders on the 1986 Depleted Uranium Waste Disposal Project at Eglin AFB and might be interested in/capable of bidding on this work.

10. Westinghouse Hitman Nuclear, Inc. Attn: Thomas Johnson,
President 9151 Rumsey Road
Columbia, Maryland 21045

Chem-Nuclear Systems, Inc.
Attn: Roger Johnson
220 Stoneridge Drive
Columbia, South Carolina 29210

12. I T Corporation
Attn: George Krauter
312 Directors Drive
Knoxville, Tennessee 37923
(615) 690-3211

13. NUS Process Services Corporation Attn: W. M. Hipsher
1501 Key Road
Columbia, South Carolina 29201
(803) 256-4355

14. Quadrix HPS, Inc.
Attn: James Thomas 111
1940 N.W. 67th Place
Gainesville, Florida 32606-1649 (904) 373-6066